

AUDITORY MASKING - A STUDY OF ITS PHYSIOLOGICAL
MECHANISM AND OF CORRELATIONS BETWEEN PHYSIOLOGICAL
AND PSYCHOLOGICAL OBSERVATIONS

Research Grant #NSG-390

Progress Report, First Quarter, Year Ended April 1, 1966

Principal Investigator:

Peter Kellaway, A. M. , Ph. D.
Professor of Physiology
Baylor University College of Medicine

Associate Investigator:

A. C. Coats, M. S. , M. D.
Assistant Professor of Physiology
Baylor University College of Medicine

Address of University:

Baylor University College of Medicine
1200 Moursund Avenue
Houston, Texas 77025

FD-503 (FORM 6-62)

66-15579

(ACCESSION NUMBER)

20

(PAGES)

CR 69420

(NASA CR OR TMX OR AD NUMBER)

(THRU)

1

(CODE)

04

(CATEGORY)

GPO PRICE \$

CFSTI PRICE(S) \$

Hard copy (HC) \$100

Microfiche (MF) 50

ff 653 July 65

Introduction

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Work during the last quarter has consisted primarily of a continuation of the psychological study of auditory masking which was begun during the latter part of the previous year. Psychological data in the following three areas has been accumulated: 1) The time course of recovery of masked click threshold following cutoff of the masking stimulus, 2) The effect of masking duration, and 3) The effect of masking intensity. Results in these three areas and the observed similarities and differences with comparable physiological observations are discussed in this report. Also, control experiments to determine the effect of a "warning flash" on the recovering click threshold are discussed.

In addition, some further physiological studies have been done. These are: 1) Further study of masked and unmasked click input-output curves, and 2) A study of the effect of masking intensity utilizing white noise instead of pure tones, as was usually done in previous studies. The results of these physiological experiments are also discussed in this report.

Author

Psychological Studies of Auditory Masking

I. The Effect of a "Warning Flash" Delivered Immediately Prior to the Recovering Test Click

Very soon after the psychological studies were begun, it became apparent that something other than the masking stimulus affected the masking-recovery curve. For lack of a better term, we have termed this the "expectancy factor".

In essence, the expectancy factor is based on the following: If it is possible to predict exactly when the test click will arrive, the threshold of the test click will be lower than if the test click arrives at an "unexpected" time. As outlined in previous reports, "psychological" masking-recovery curves are obtained by delivering a single test click after masking cutoff and tracking its threshold with a recording attenuator. Test click thresholds at several post-masking intervals are obtained. We have found that in this situation the subject uses the masking stimulus as his "cue" to time the arrival of the test click. This is done by making a judgment of the time interval separating the masking stimulus (actually the cutoff of the masking stimulus) and the test click. This interval judgment is "set" with the first few pairs of stimuli, and on subsequent pairs is used to predict the time of arrival of the test click, and thereby to lower test click threshold. Since, however, long intervals are more difficult to judge accurately than short intervals, the "expectancy factor" operates to increase test-click threshold at longer post-masking intervals. Thus, because of the "expectancy factor", masking-recovery curves which were obtained early in the course of this study showed a distinct tendency to "sag" at longer post-masking intervals.

In order to hold the "expectancy factor" constant, a "warning flash" has been placed into the stimulus sequence. This consists of a light flash delivered 200 msec prior to the test click. The 200-msec interval remains constant throughout the experimental run, and the interval between masking cutoff and the flash-click pair is varied. The subject is instructed to ignore the masking stimulus (as best he can) and to use the flash to determine the exact time of

arrival of the test click.

We have completed several control experiments in which masking-recovery curves have been obtained with and without the warning flash. Following are the results of these experiments:

1) No qualitative alteration in the results so far obtained (i. e. the masking-duration and masking-intensity studies described below) is produced by the warning flash.

2) However, the following quantitative alterations in the results obtained were consistently observed:

a) The variability of recovering click threshold (i. e. the excursion of the attenuator pen when click threshold is being traced) is significantly reduced - particularly at long cutoff-test click intervals.

b) The tendency for click threshold to rise at long cutoff-test click intervals was completely eliminated.

These control experiments have led us to the conclusion that the addition of the "warning flash" to the masking stimulus-test click sequence significantly increases the quality of the data obtained. The warning flash has therefore been adopted as a standard part of our experimental procedure.

II. Time Course of Recovery from Masking of Click Threshold

Typical human masking-recovery curves are shown in Figs. 1, 3, and 4. It is apparent that the human masking-recovery curves show the same "logarithmic increment" form that the animal recovery curves show. An occasional

curve shows some irregularity, usually occurring very shortly after cutoff of the masking stimulus (see Fig. 4). However, such irregularities did not appear consistently, and the recovery time course is therefore interpreted as essentially monotonic.

It is to be noted, however, that while the masking-recovery curves obtained from humans appear to be qualitatively very similar to the recovery curves obtained from animals, we have not as yet excluded the possibility that a significant quantitative difference exists between the two. For example, it appears that psychological masking recovery may be significantly faster than physiological recovery.

III. The Effect of Duration of the Masking Stimulus

The effect of masking duration in the psychological experimental situation appears to be very similar to its effect in the physiological situation. We have previously reported that increasing masking duration has no effect on masked click action-potential amplitude, but slows recovery. Thus, A. P. masking-recovery curves following short- and long-duration masking start from the same point (i. e. the masked click A. P. amplitude), diverge in the early phases of recovery, then reconverge as recovery nears completion. As illustrated by Fig. 1, recovery of human click threshold following long- and short-duration masking shows an identical pattern.

Also, a psychological masking-duration effect identical with the previously described physiological masking-duration effect was consistently observed. An example is shown in Fig. 2.

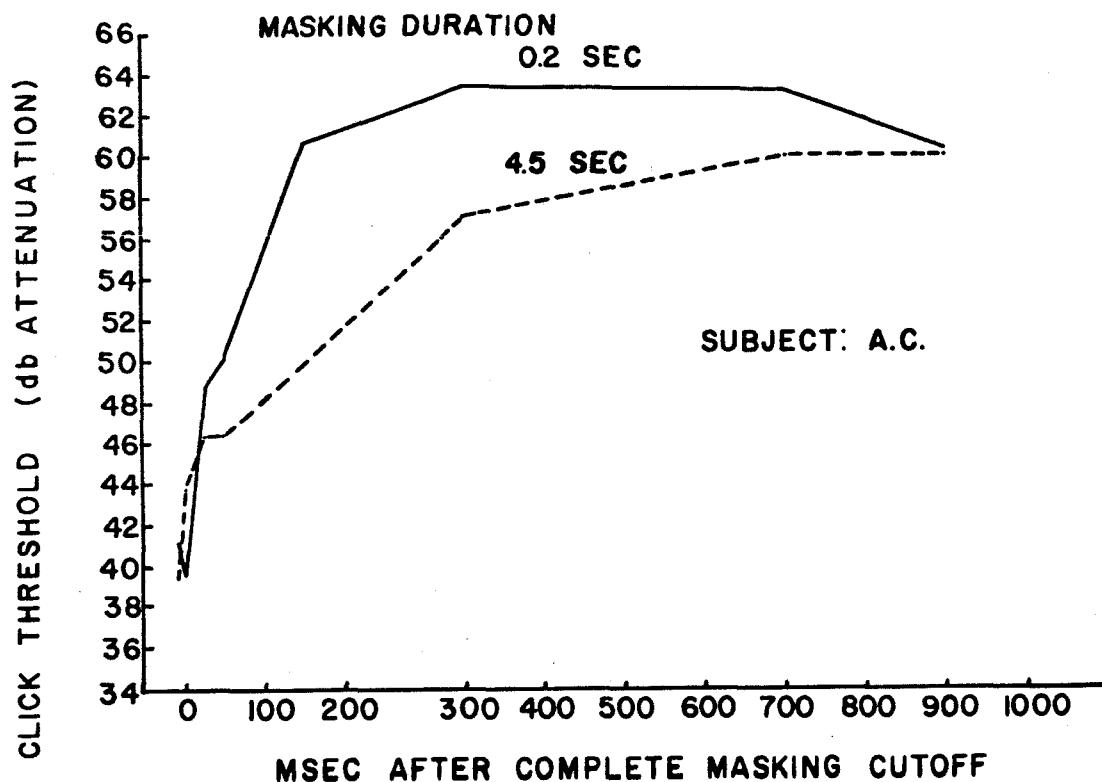


Fig. 1. Effect of masking duration on the time course of recovery from masking. These curves represent plots of the thresholds of single clicks occurring at different post-masking intervals. The single click thresholds were obtained with a recording attenuator. The masked (click) stimuli were produced by driving a PDR-600 earspeaker with a square-wave pulse 60 V in amplitude and 0.01 msec in duration. This driving pulse was led through the recording attenuator. The masked stimulus was a 2,500 cps pure tone of 75 db intensity. Rise-fall time was 5 msec.

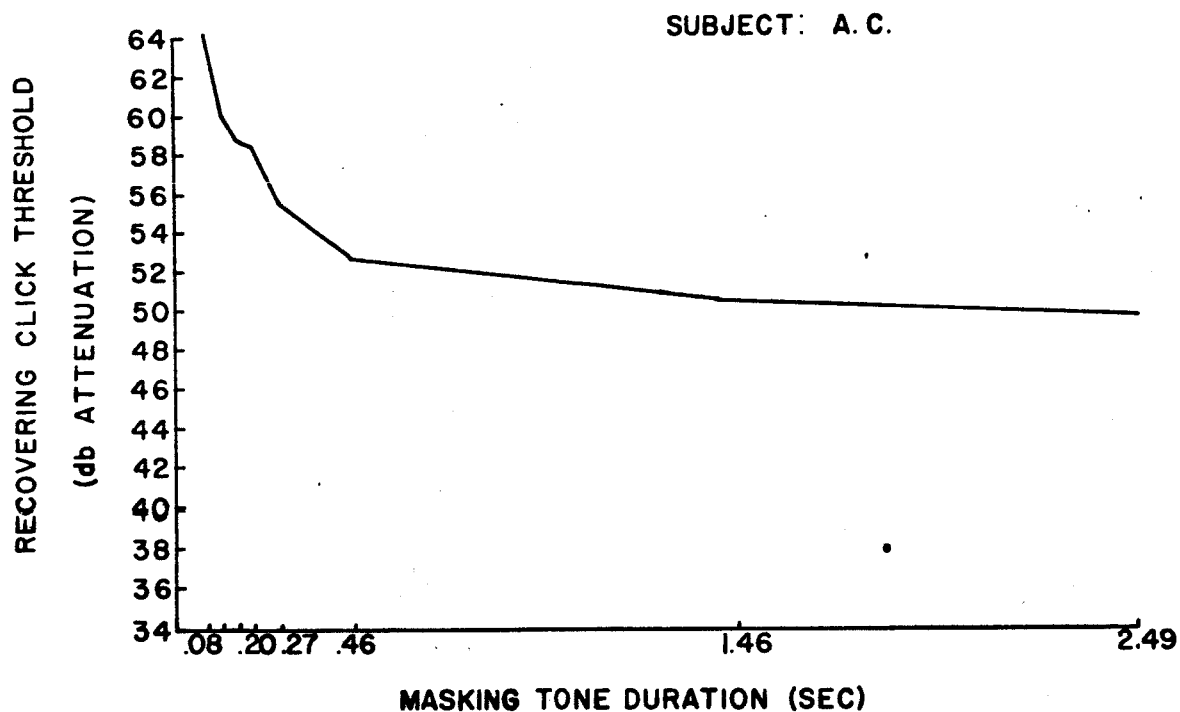


Fig. 2. Psychological masking-duration effect. To obtain this plot, the masking cutoff-test click interval was held constant (100 msec) and the duration of the masking stimulus was varied. The threshold of the test ("recovering") click is plotted against the duration of the masking stimulus. The test click was produced by driving a PDR-600 earspeaker with an 0.01 msec, 60 V square-wave pulse. Masking stimulus: 70 db, 2,000 cps tone with rise-fall time of 5 msec.

IV. The Effect of Intensity of the Masking Stimulus

As previously reported, physiological studies have shown that increasing masking intensity lowers the point from which the masking-recovery curve starts (i. e. reduces the amplitude of the masked action potential). However, increasing masking intensity does not alter the time course of the early phase of masking recovery. Thus, previously obtained physiological data show that the early part of the recovery curve following the more intense of two masking stimuli will lie beneath the recovery curve following less intense masking by a constant amount. As illustrated by Figs. 3 and 4, the same holds true for psychological data.

Physiological Studies of Auditory Masking

I. Further Studies of Masked and Recovering Click Input-Output Curves

In previous progress reports, the results of masked (or "recovering") and unmasked (or "control") click input-output experiments have been outlined. These experiments showed that if masking intensity is less than about 60 db, the difference between the masked and unmasked input-output curves is constant above a certain click intensity. In other words, if the difference between the masked and unmasked input-output curves is plotted, this "difference curve" will show a "plateau" above a certain click intensity. At masking intensities above about 70 db, however, the "difference curve" shows no such "plateau".

All of the above observations were made with pure-tone masking. In the last quarter, these observations have been repeated with white-noise masking.

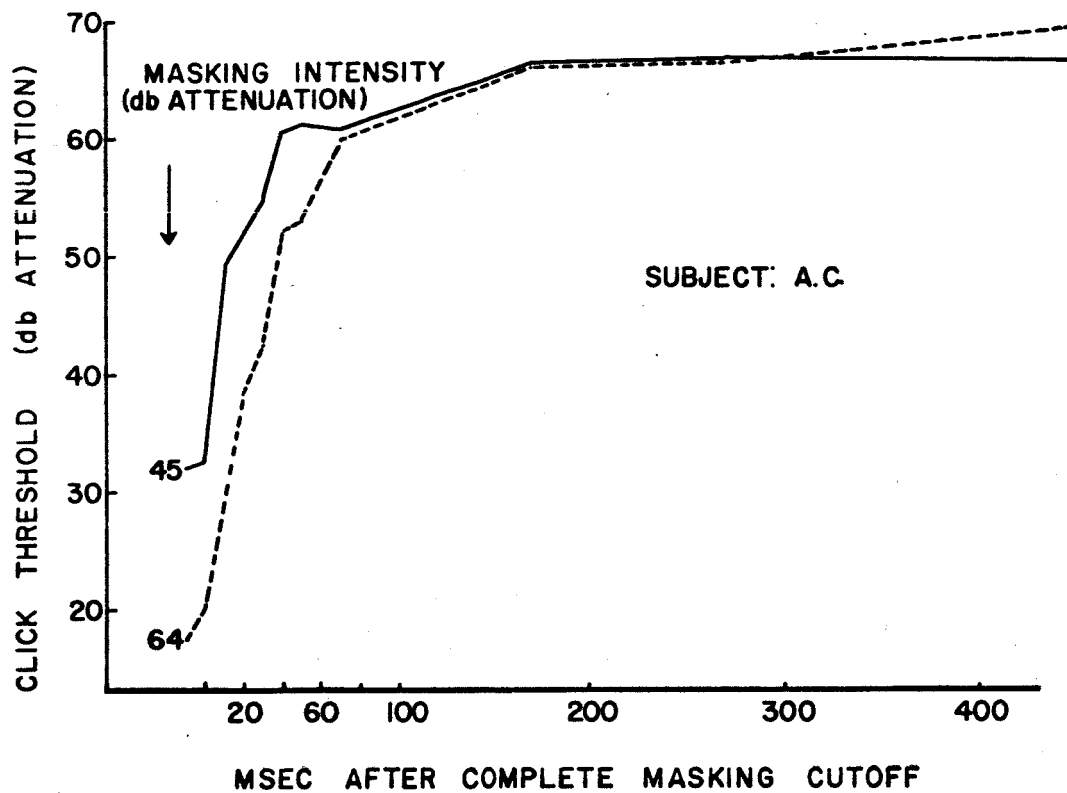


Fig. 3. The effect of masking intensity on the recovery of masked click A. P. threshold. Test clicks were produced by driving a PDR-600 earspeaker with square-wave pulses 0.1 msec in duration and 75 volts in amplitude. The square waves were led through the recording attenuator. The masking stimulus was a 1.7 sec burst of white noise with rise-fall time of 5 msec.

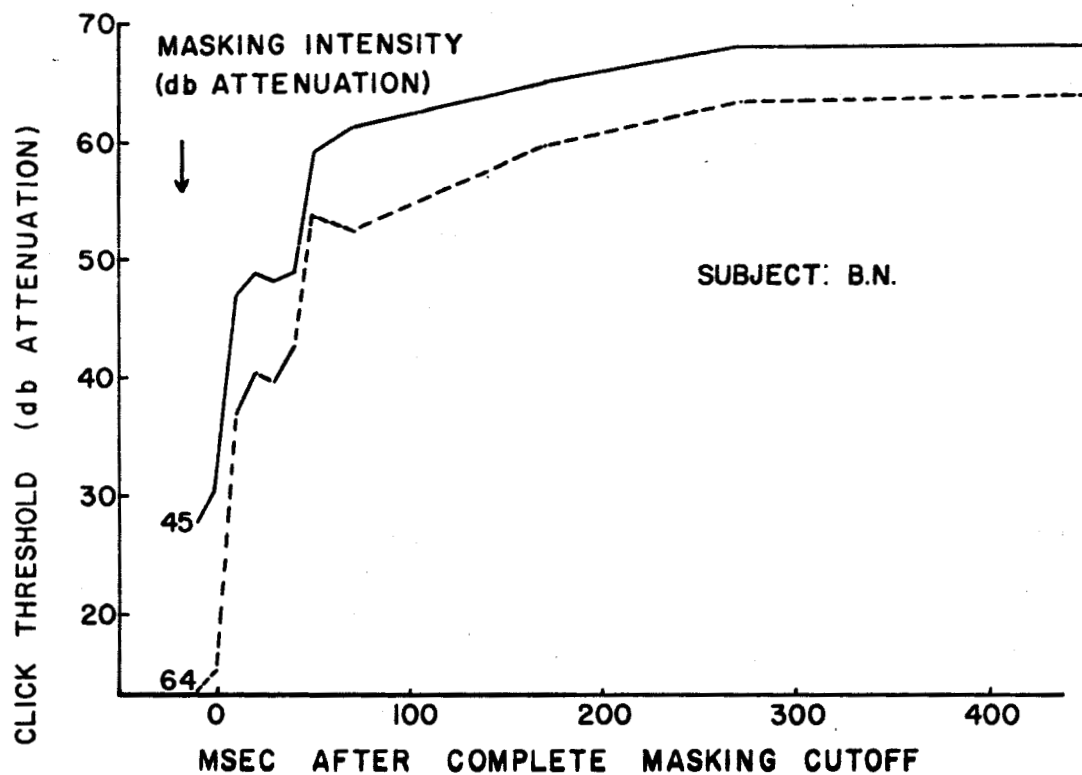


Fig. 4. The effect of masking intensity on the recovery of masked click A.P. threshold. All stimulus parameters are the same as for Fig. 3. However, these curves were obtained from a different subject.

The results of one such experiment are shown in Fig. 5. In this figure are plotted the unmasked click input-output curve and difference curves for a series of masking intensities. As can be seen, masking intensity was varied by 5-db steps.

The following are apparent from an examination of Fig. 5:

1) "Plateaus" can be seen in the difference curves obtained with masking intensities of 40, 35, and 30 db attenuation. Thus, a "plateau" in the masked-unmasked difference curve is obtained with white-noise as well as with pure-tone masking.

2) The transition between "plateau" and "no plateau" is not sharp, and, in fact, one might interpret the curves at 5 and 0 db as showing a slight plateau (though beginning at a much higher click intensity).

3) The masking intensity at which a distinct "difference plateau" ceases to be readily apparent is in the range of 26-36 db (30-40 db attenuation from reference intensity of 66 db). This contrasts sharply with the 70 db "transition intensity" observed with pure-tone masking.

These observations are in agreement with the generalization, made from previous observations, that the only difference between pure-tone and white-noise masking (where clicks are the masked stimuli) is that white noise is a much more effective masking stimulus than is a pure tone. In other words, the difference between white-noise and pure-tone masking is quantitative and not qualitative.

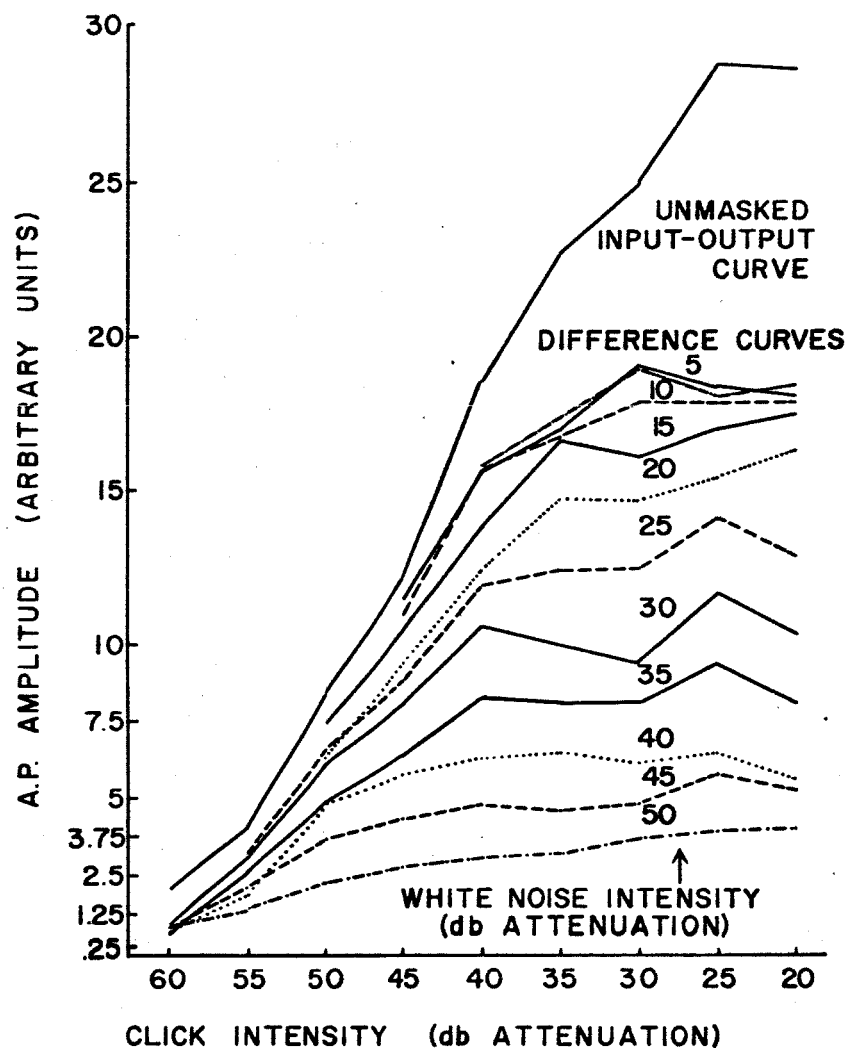


Fig. 5. Click input-output "difference curves" at different masking intensities. Each difference curve was constructed by subtracting the appropriate recovering input-output curve (not shown) from the unmasked input-output curve. The test click stimuli were produced by driving a PDR-600 earspeaker with an 0.01 msec, 40 V square wave. The driving pulse was led through a decade attenuator. The masking stimulus was a 1.25 sec burst of white noise turned on and off with a 5-msec rise-fall time. The intensity of the white noise at 0 db attenuation was 66 db. The test clicks were delivered 5 msec after masking cutoff was complete.

II. The Effect of Masking Intensity on Recovering A. P. Amplitude

In Fig. 6 is shown a plot of recovering action-potential amplitude versus masking intensity. The same data plotted in Fig. 5 were used to obtain these plots. In Fig. 7 is shown a comparable plot where a pure tone rather than white noise was the masking stimulus. We have suggested that the "knee" in the region of 50-60 db masking intensity (20 db attenuation) suggests the possibility of a transition zone in this region. The white-noise intensity curves (Fig. 6) also show a possible "knee" in the region of 50-60 db. However, as is readily apparent, the form of the curves above and below the "knee" is exactly opposite the form above and below the "knee" when pure tones are used as the masking stimuli. With pure tones, the rate of decrease of masked A. P. amplitude above the knee is clearly greater than the rate of decrease below the knee. With white noise, exactly the opposite is true.

Thus, when the effect of masking intensity on recovering A. P. amplitude is studied, we find a qualitative difference between white-noise and pure-tone masking, and the previously suggested generalization that only quantitative differences between these two stimulus types exist appears not to hold in this instance.

Future exploration of this apparent difference is planned. Of great importance will be experiments in which masking intensity-masked A. P. amplitude curves are obtained with pure tone and white noise from the same preparation.

Also of considerable importance will be an extension of the white noise intensity range studied above that shown in Fig. 6.

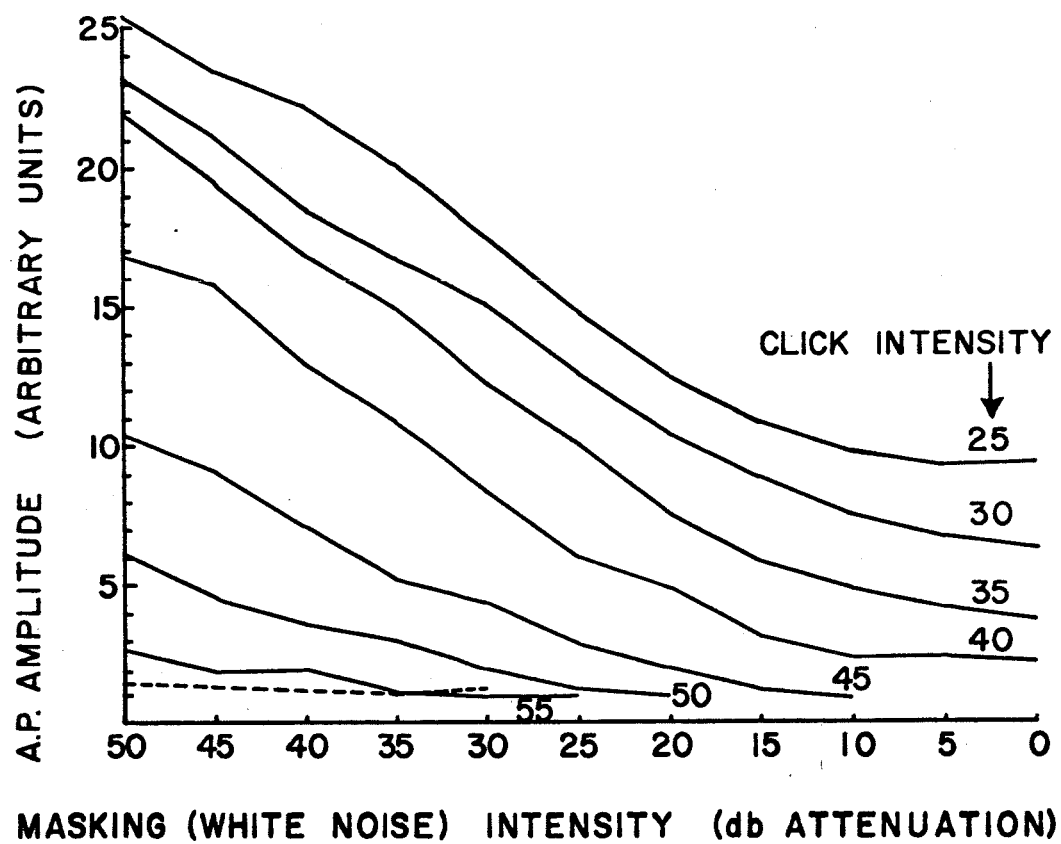


Fig. 6. Recovering action-potential amplitude versus masking intensity. A replot of the same data presented in Fig. 5.

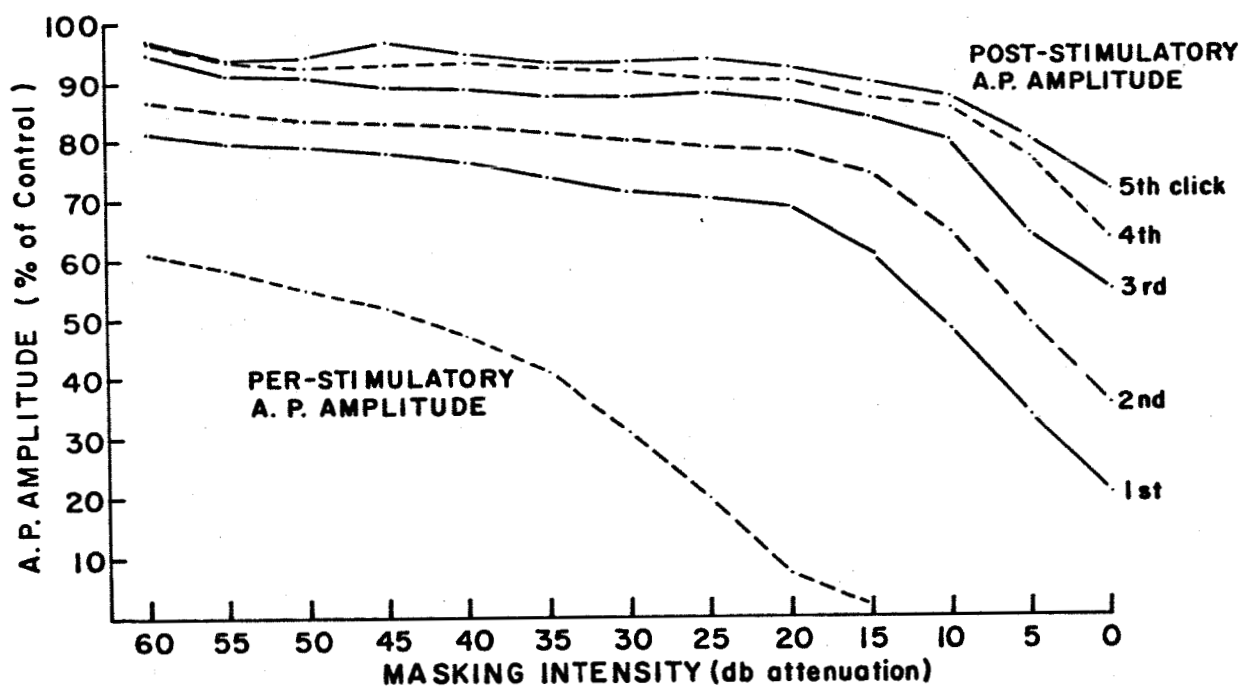


Fig. 7. Masked ("per-stimulatory") and recovering ("post-stimulatory") action-potential amplitude versus masking intensity. The masking stimulus was a pure tone. Compare the knee at 20 db attenuation with the "knee" in Fig. 6 where white noise was the masking stimulus. The test clicks were produced by driving a PDR-600 earspeaker with a train of 0.15 V square-wave pulses, 0.01 msec in duration. Click rate was 20/sec. Masking stimulus was a 2,500 cps tone, 0.3 sec in duration. Intensity at 0 db attenuation was 82.5 db.

It is possible that these planned experiments will lead to a further elucidation of the nature of the "transition zone" found in the 50-60 db intensity range.